

ECONOMIC CONSEQUENCES OF IMPROVED
TEMPERATURE FORECASTS: AN EXPERIMENT WITH
THE FLORIDA CITRUS GROWERS

(CONTROL GROUP RESULTS)

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EXECUTIVE SUMMARY



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FINAL

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ABSTRACT

NASA is planning a demonstration experiment (to be initiated in late 1977) to show that frost and freeze prediction improvements are possible utilizing timely Synchronous Meteorological Satellite (SMS/GOES) temperature measurements and that this information can affect Florida citrus grower operations and decisions so as to significantly reduce the cost for frost and freeze protection and crop losses. As part of this effort, ECON, Inc. has designed and conducted the first phase of an economic experiment which will monitor citrus growers' decisions, actions, costs and losses, and meteorological forecasts and actual weather events and will establish the economic benefits of improved temperature forecasts. The economic experiment is designed to measure the change in annual protection costs and crop losses which are the direct result of improved temperature forecasts.

To estimate the benefits that may result from improved temperature forecasting capability, control and test groups have been established with effective separation being accomplished temporally. The control group, utilizing current forecasting capability, was observed during the 1976-77 frost season. The test group, benefiting from improved temperature forecasting capability expected to result from the utilization of SMS/GOES data in combination with forecast models being developed by the University of Florida, will be observed during the 1977-78 and possibly following frost seasons. The economic benefits of the improved forecasting capability will then be the difference between normalized costs and losses of these two groups extrapolated across the State of Florida.

This report presents a brief overview of the economic experiment, the results obtained to date, and the work which still remains to be done.

ACKNOWLEDGEMENTS

ECON, Inc. acknowledges the contributions of Chris Braen, Edward Gallagher, Joel S. Greenberg, Keith Lietzke, Dr. Dan Nikodem and Dr. Francis Sand who performed the analyses which are summarized in this report. Technical assistance was also provided by Peter Stevenson. The economic experiment described in this report could not have been accomplished without the close cooperation of the National Weather Service, Florida County Extension Service, Federal Crop Insurance Corp., and the University of Florida. Particular appreciation is extended to the 52 Florida citrus growers who provided the crop protection and damage data which is the very essence of this experiment, and to John Jackson, Tom Oswalt, Ed Richards, Jack Hayman, Bill Phillips and Tim Hurner, the county extension agents, who played a key role in the overall data-gathering process. The reported experiment was under the technical direction of Mr. Ernest Neil at NASA's Goddard Space Flight Center.

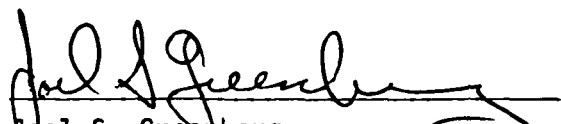
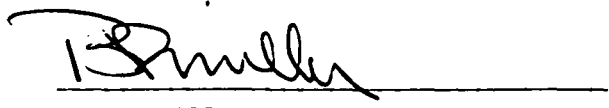

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1. INTRODUCTION

NASA is planning a demonstration experiment (to be initiated in late 1977) to show that frost and freeze prediction improvements are possible utilizing timely Synchronous Meteorological Satellite (SMS/GOES) temperature measurements and that this information can affect Florida citrus grower operations and decisions so as to significantly reduce the cost for frost and freeze protection and crop losses. As part of this effort, ECON, Inc. has designed and conducted the first phase of an economic experiment designed to monitor citrus growers' decisions, actions, costs and losses, and meteorological forecasts and actual weather events and to establish the economic benefits of improved temperature forecasts. The economic experiment^{*} is designed to measure the change in annual protection costs and crop losses which are the direct result of improved temperature forecasts. The first phase of the experiment has been completed and is reported herein. It should be noted that the reported economic experiment must, of necessity, encompass data collection during several frost seasons, only one of which has occurred. Therefore, no conclusions can yet be drawn relative to the magnitude of the economic benefits which may result from improved temperature forecasts provided to the Florida citrus growers.

2. CITRUS GROWER'S DECISIONS

The citrus grower, upon receipt of a forecast for temperatures below approximately 28°F, must decide whether or not to protect his crop. Normal protective measures include the firing of diesel heaters or the use of electrically operated wind machines. Decisions must be made with respect to when to call in crews, when to turn heaters and/or wind machines on and off and how many heaters to utilize. These decisions affect citrus crop protection costs and losses resulting from inadequate protection measures.

^{*} Described in "A Plan for Application System Verification Test--The Value of Improved Meteorological Information," ECON, Inc. Report No. 76-108-2, August 31, 1976, prepared under NASA Contract No. NASW-2558.

The purpose of the economic experiment is to determine the magnitude of the benefits which may result from improved temperature forecasts to the citrus growers. The benefits may result from cost reductions, loss reductions, and improved marketing decisions which may be the result of improved knowledge of previous nights' temperature distribution across the state. This latter benefit area, though possibly large, is not considered in the current experiment and will not be discussed further. Cost reductions will result from improved scheduling of crews due to false alarm (forecast for temperatures which would normally require the initiation of protective measures but, in actuality, the potentially damaging temperatures do not occur) reductions and improved timing of the initiation and termination of protective measures. Loss reductions will result from improved scheduling of crews due to probability of miss (the likelihood of forecasting temperatures for which protective action is not required when, in actuality, temperatures occur at which protective action is required) reduction and improved timing of the initiation and termination of protective measures.

Table 1 illustrates, through the use of a hypothetical though typical example, the costs and losses which may result from a grower's protection decision and actual freeze severity given a freeze forecast for minimum temperatures less than 28°F. Two situations are shown and compared, namely, (a) the grower's decision was not to protect, and (b) the grower's decision was to protect. In each case the results are illustrated, given that no freeze developed, a moderate freeze developed, and a severe freeze developed. Indicated in the table are the cost of protection, the price before the freeze, the price after the freeze (this price is a function of the freeze severity since it is assumed that, independent of the specific grower protection decision, damage will be inflicted by the freeze on other groves throughout the state of Florida and will, therefore, affect supply which in turn affects price), the expected yields before and after the freeze and resultant physical losses.

It should be noted that protection cost is a function of the protection decision and the severity of the freeze. It should also be noted that the yield expected after the freeze is a function of both the protective decision and the severity of the freeze. The effect of the grower's protection

Table 1 An Illustrative Example of Costs and Losses In Terms of Grower's Protection Decisions and Freeze Severity*

	No Protection			Protection		
	No Freeze	Moderate Freeze	Severe Freeze	No Freeze	Moderate Freeze	Severe Freeze
Cost of Protection (\$/Acre)	0	0	0	3.26	15.85	67.52
Price Before Freeze (\$/Box)	2.50	2.50	2.50	2.50	2.50	2.50
Price After Freeze (\$/Box)	<u>2.50</u>	<u>3.00</u>	<u>3.25</u>	<u>2.50</u>	<u>3.00</u>	<u>3.25</u>
Change in Price Due to Freeze (\$/Box)	0	0.50	0.75	0	0.50	0.75
Yield Expected Before Freeze (Box/Acre)	350	350	350	350	350	350
Yield Expected After Freeze (Box/Acre)	<u>350</u>	<u>170</u>	<u>50</u>	<u>350</u>	<u>330</u>	<u>300</u>
Physical Losses (Box/Acre)	0	180	300	0	20	50
Revenue Gains or Losses** (\$/Acre)	0	-365	-712.50	0	+115	+100
Economic Gains or Losses+ (\$/Acre)	0	-365	-712.50	-3.26	+99.15	+32.48
Value of Protection to Grower This Night++ (\$/Acre)	--	--	--	-3.26	+464.15	+744.98

* It is assumed that on this night a freeze was forecast with minimum temperature less than 28°F.

** (price before freeze x yield expected before freeze) - (price after freeze x yield expected after freeze).

+ revenue change due to protective action less the cost of protection.

++ economic gains or losses with protection less the economic gains or losses without protection.

decision and severity of freeze is thus seen in terms of cost of protection and physical losses (boxes/acre). The grower may be better or worse off, depending upon the combination of the change in price due to the freeze and the effectiveness of grower protective action. This is shown as the revenue gains or losses (\$/acre) and may range from a large loss (\$712.50/acre when no protection is undertaken and a severe freeze occurs) to a large gain (\$100/acre when effective protective action is taken and a severe freeze occurs). The economic gains or losses to the particular grower are thus the revenue gains or losses less the cost of protection.

The value of protective action to the grower for the specific case illustrated in Table 1 is the difference between the economic gains or losses with and without protective action for the same level of frost severity. It should be noted that this example did not take into account the likelihood of freeze severity given a specific temperature forecast. This is an important factor which temporizes the numbers illustrated in Table 1 and is taken into account in the development of experiment results.

It has been estimated that as much as \$5 million is spent on frost protection measures by the Florida citrus growers on a severe frost night. In light of the continuing increase in diesel and gasoline prices, this nightly cost may rise dramatically in the near future or losses from lack of protection may increase. In the event of tree and fruit damage, the statewide dollar loss may be measured in many millions of dollars, as this past winter has shown. Any possible reduction in both the nightly costs of frost protection and extent of freeze damage will be closely related to the strategy the growers employ once frost has been forecasted. Though many factors influence the grower's initial decision to protect and his nightly strategy, a most important factor is the confidence given to the temperature forecasts. It is felt that the satellite forecast system scheduled for operation by winter 1977 will better assist the individual grower, not only in his initial protection decision, but, more importantly, during the hour-by-hour "wait and watch" period when frequent temperature updates are received.

3. THE ECONOMIC EXPERIMENT

In order to measure the economic benefits of improved temperature forecasts it is necessary to establish and then compare the nightly costs and losses experienced by growers resulting from (1) using the improved forecasts and (2) using the present forecast system. To this end, control and test groups have been established. Effective separation between the two groups of sample growers is accomplished temporally. The control group, utilizing current forecasting capability, was observed during the 1976-77 frost season. The test group, benefiting from the improved temperature forecasting capability that will result from the utilization of SMS/GOES data in combination with forecast models being developed by the University of Florida, will be observed

during the 1977-78 and possibly following frost seasons. The economic benefits of the improved forecasting capability will then be the difference between the normalized costs and losses of these two groups extrapolated across the state of Florida.

During the previous year's activity, the details of the experiment design were developed, data collection methodology and procedures were determined, control group data collection was undertaken and completed, data reduction techniques developed and implemented, and economic analyses undertaken. The previous year's work also resulted in the development of the experiment sampling plan, the methodology for establishing protection costs and losses resulting from inadequate protection in terms of temperature forecasting capability, and the development of the means for collecting data which would demonstrate the economic (and fuel conservation) consequences of improved temperature forecasting.

Preliminary cost and loss determination methodologies were determined and detailed citrus grower and National Weather Service data requirements were determined. Finally, data forms were developed which placed major emphasis upon minimizing the data collection burden on the grower. Three data forms were developed: one to gather data which may be considered as invariant during the frost season; one to gather data on the daily protection costs, events, decisions and actions; and one to gather data on fruit and tree damage. These forms were filled out for each of the groves in the sample. Sources were also developed and data obtained for citrus spot and future prices, and fuel prices.

Cost and loss determination methodologies have been developed and result in the determination of the average cost and loss per frost event per grove. The methodology allows a "normal" or average frost season to be defined in terms of number of days of different levels of frost severity at each grove. Normalized annual costs and losses for both the control and test groups are to be established, the difference between these costs and losses will be the annual benefit of the improved forecasts to the citrus growers comprising the sample. Procedures have also been developed for extrapolating these results across the Florida citrus industry, taking into account such factors as citrus type, grove location, frost protection practices, frost occurrences, and the Federal Crop Insurance Corporation indices.

Methods and procedures have been developed for establishing a frost severity index based upon the duration of different levels of frost and its impact (damage) on fruit and trees. This requires knowledge of the grove temperature (as a function of time) that would have occurred in the grove if protective action were not taken. To accomplish this, methods were devised for relating National Weather Service control thermometer thermographs to grove temperature (for each grove in the database) which are then used to establish the grove frost severity index for each night of frost.

The developed data collection procedures were implemented for a control group consisting of 245 groves operated by 52 growers. With the assistance of the county extension agents, Grove Background Reports were obtained for the 245 groves. Approximately 2150 Nightly Frost/Freeze Protection Activity Reports and several hundred Damage Reports were obtained. Additional data was provided by the Florida Crop and Livestock Reporting Service and the Federal Crop Insurance Corporation. The NWS has provided all necessary weather forecasts and control thermometer thermographs. In addition, the NWS has provided detailed temperature records of the past thirty years so that a "normal" or average year can be ascertained for control and test group comparisons.

The collected data forms have been reviewed, data transformed and entered into a computerized database. This database (of the control group) is utilized in the determination of events and average annual costs and losses. Daily costs and losses have been established for each grove and classified by event type, citrus grower type, and frost severity. Average costs and losses have been determined and annual costs and losses established for this control group. The developed capability, with suitable modifications to take into account price variations between control and test group years, will allow the results of the control and test groups to be compared and the annual demonstrated benefits to be established. These benefits, based upon the sample population, will be extrapolated to total Florida citrus industry annual benefits, taking into account grower geographic locations, geographic temperature patterns, grower crop protection capabilities, and crop type. The net result will be the establishment of demonstrated benefits and extrapolated (from the measured benefits) benefits which are the direct result of improved frost protection decisions made possible by improved temperature forecasting capability.

The economic experiment is a cooperative venture between many individuals and agencies. The major participants in the experiment and their roles are indicated in Figure 1.

4. CONTROL GROUP RESULTS

The control group results are based upon data provided by 52 growers for 245 groves for which they have management responsibility. Indications are that the control group represents approximately a 20-percent sample based upon number of protected groves and a 17-percent sample based upon protected acreage. The geographic distribution of the experiment sample population is illustrated in Figure 2.

Typical control group results are illustrated in Figures 3 through 6. Figure 3 illustrates the average of mean severity (in terms of a severity of frost index which is a function of temperature and duration, and its impact on citrus and trees) of frost by date. Two columns are shown for

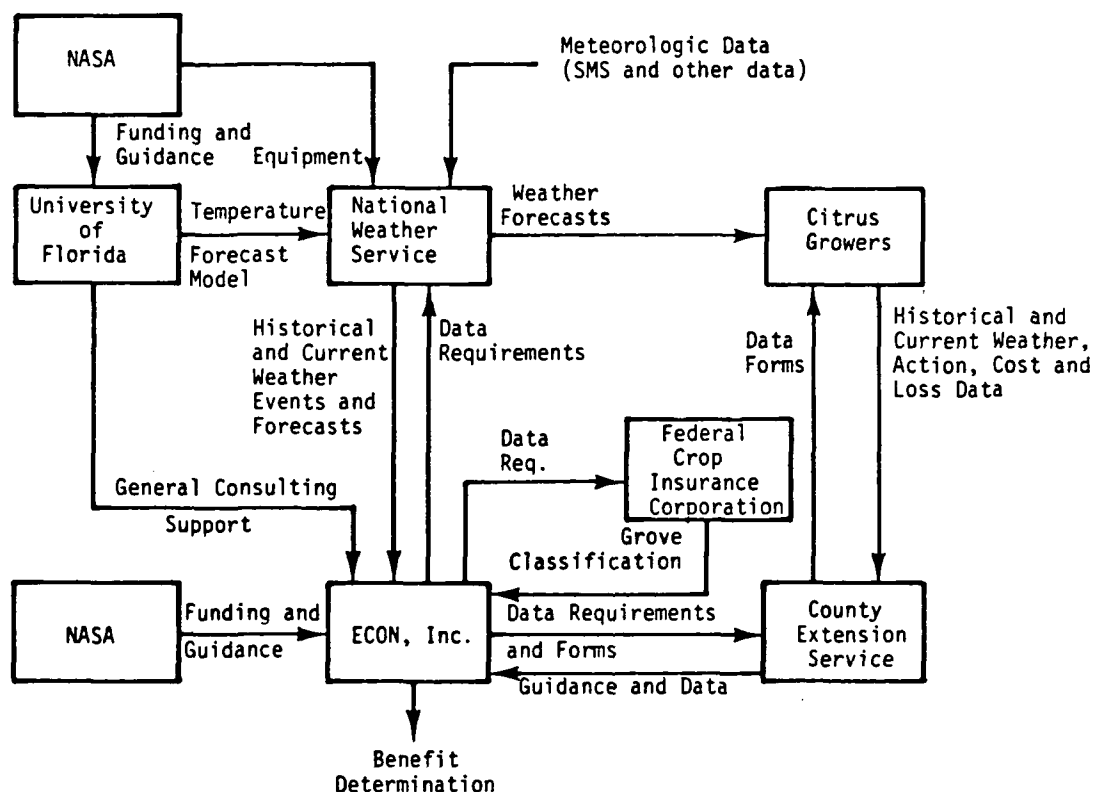


Figure 1 Participants in the Florida Economic Experiment

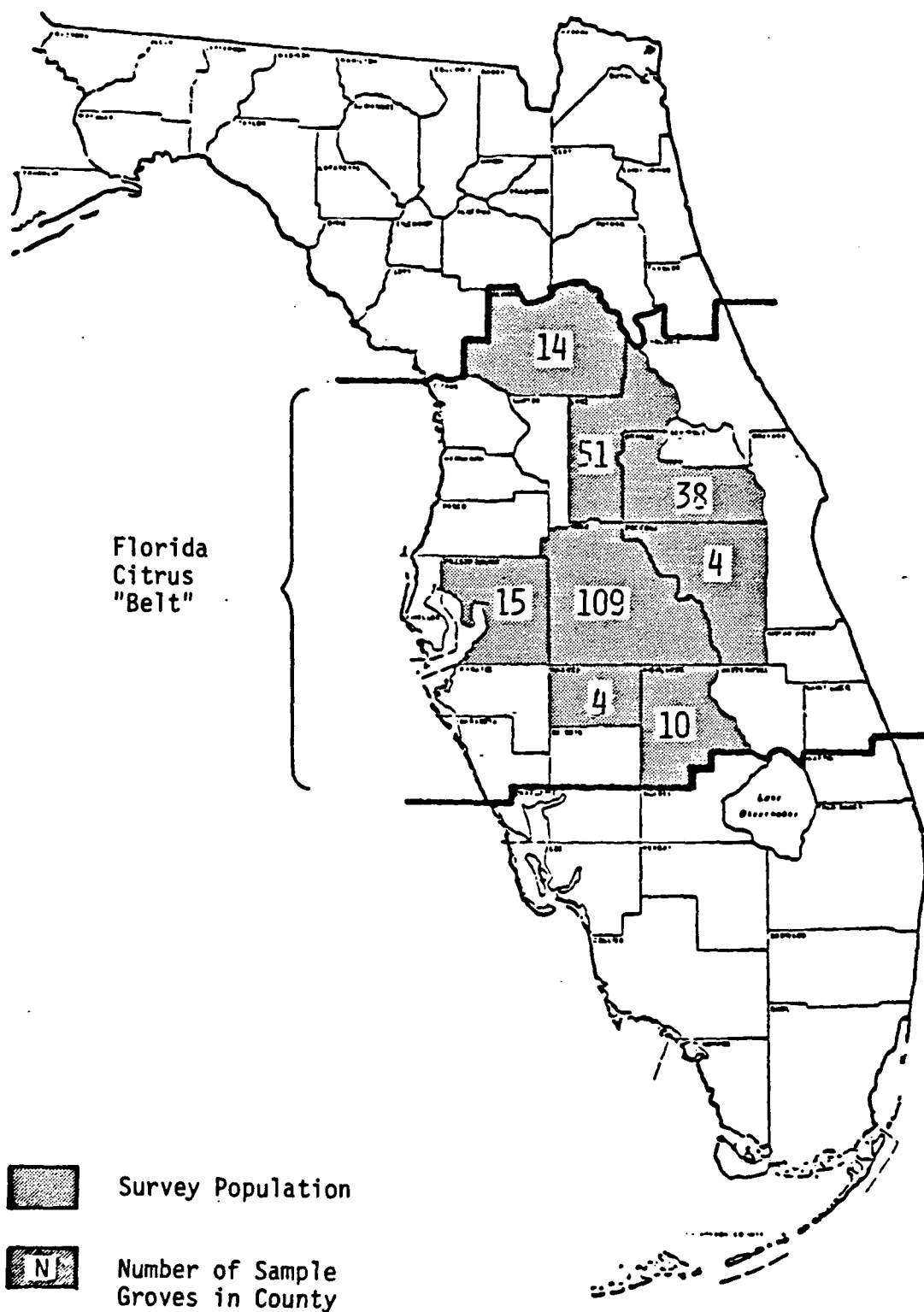


Figure 2 Sample Grove Distribution

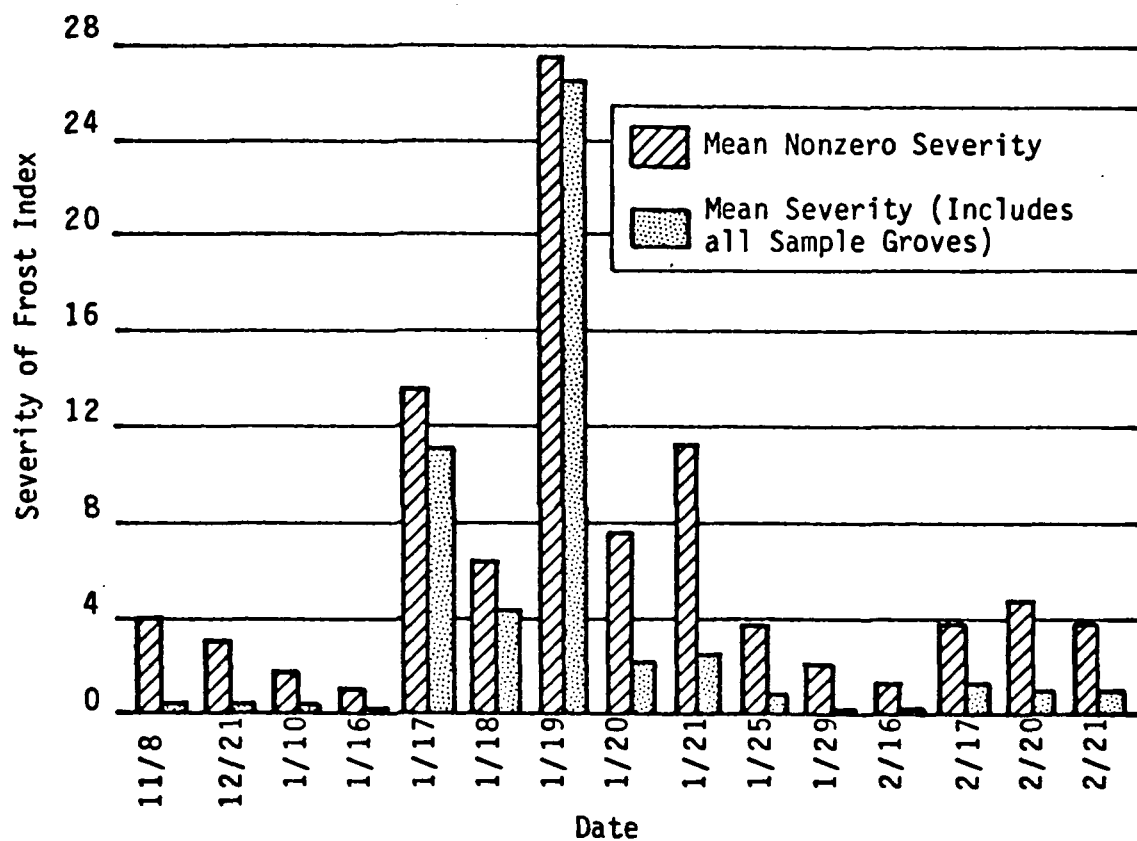


Figure 3 Mean Severity of Frost by Date (1976-77)

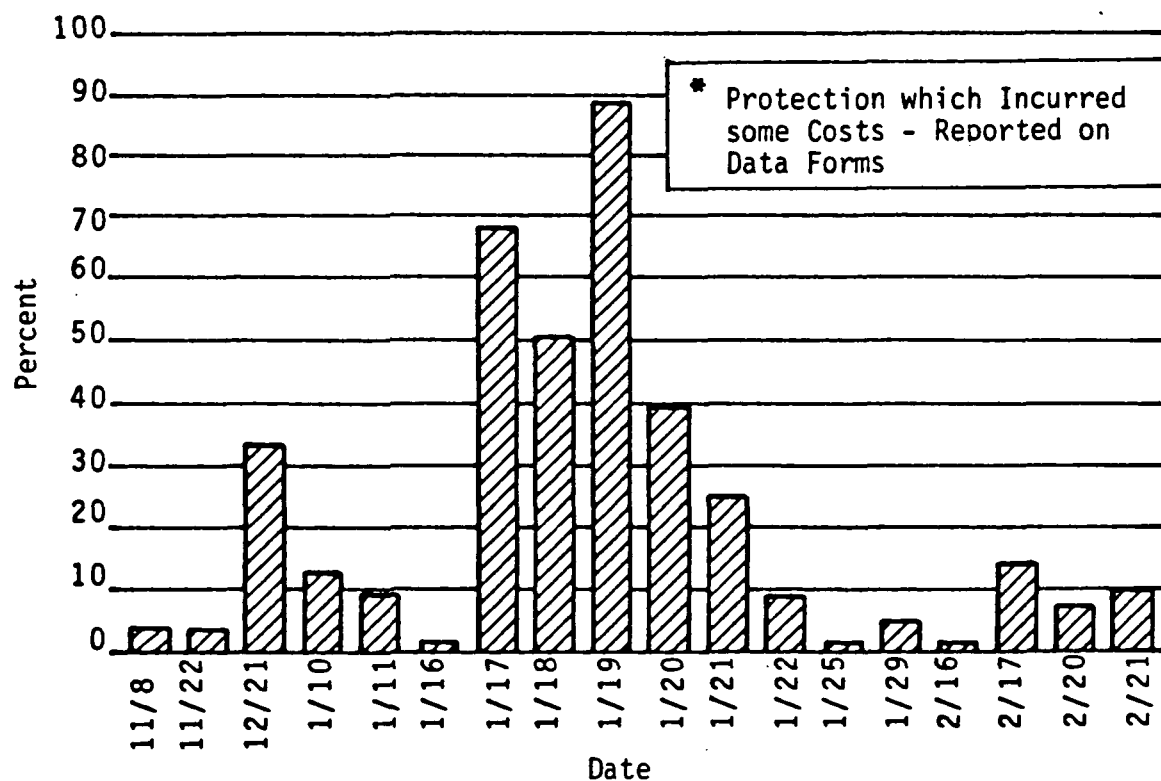


Figure 4 Percent of Sample Groves Undertaking Protection on Each Cold Night (1976-77)

each day; the column on the left indicates the mean severity when considering only those groves for which freezing temperatures (i.e., below 28°F) were experienced, whereas the column on the right indicates the mean severity when considering all groves in the database. The difference in the height of these columns is a measure of the lack of uniformity of the frost.

Figure 4 illustrates the percent of sample groves undertaking protective action on each cold night and Figure 5 indicates the average per acre cost of protection on each cold night for groves that experienced protection costs and for all groves in the database. The average cost of protection for the 1976-77 crop year varies considerably by county, ranging from a high of \$109/acre in Hillsborough to a low of \$32/acre in Marion County. Because of these variations, all analyses and extrapolations must be done by citrus variety and county.

Figure 6 indicates the physical losses for all groves in the control group sample, by frost date. There are two types of losses that can occur

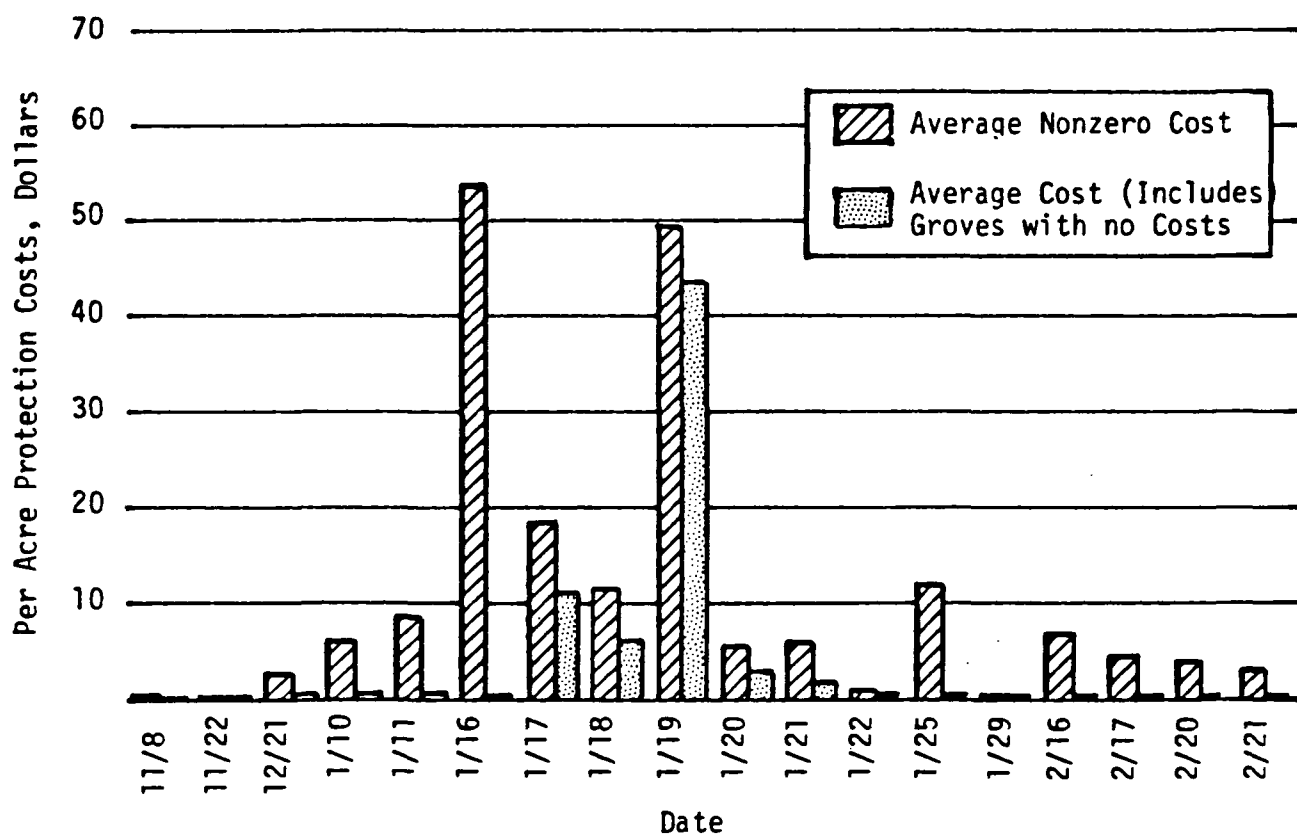


Figure 5 Average Per Acre Cost of Protection for Each Cold Night (1976-77)

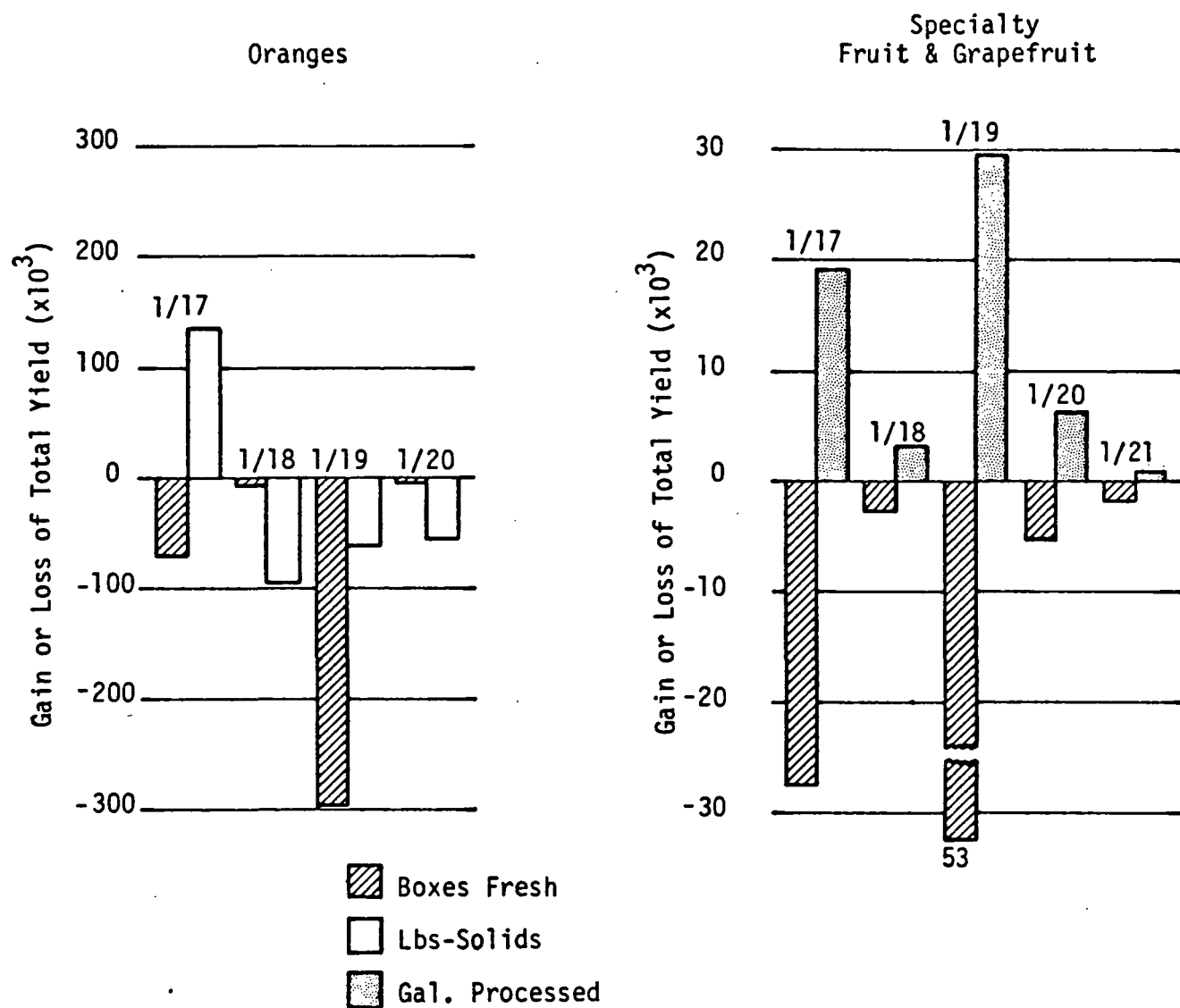


Figure 6 Gain or Loss by Night for Groves in Control Group Sample Which Suffered Crop Damage (1976-77)

due to a freeze. One is a loss of quantity, when fruit is so badly damaged that it drops to the ground or is not worth picking. The second is a loss of quality, when fruit which was originally intended for the fresh market is no longer suitable for fresh sale and must be processed, or when fruit intended for processing loses some of its sugar and juice content so that its yield in pounds-solids declines.

Some growers in the sample experienced total losses of all or part of their fresh or processed fruit. Most were able to save their fruit by diligent protection, but in many cases the damage caused a shift of marketing plans from the fresh sector to the processed one, or a loss in pounds-solids. On the average, a large amount of fresh fruit was lost on each of the frost/freezing nights, but due to the shift from fresh to processed, there was a samplewide gain in pounds-solids. Because of some absolute losses, and because of the overall decline in the juice and sugar content in the total crop, these gains do not totally offset the fresh fruit losses.

Figure 6 indicates the loss of fruit intended for the fresh fruit market and the gain in fruit for the processed market--the gain is the net of fruit intended for fresh but marketed as processed and the yield reduction of that fruit originally intended as processed.

Regression analyses are underway to relate the developed data on costs and losses to the frost severity index. As of the date of this report, no conclusive results have been obtained on the cost-loss-severity relationship due, primarily, to the late arrival of damage report data from the growers.

The data presented in the previous tables and figures are based upon information provided by the Florida citrus growers. The basic data were provided by 52 growers covering 245 groves; 2150 Nightly Frost/Freeze Protection reports were provided by the growers. These reports are filed whenever a frost is forecast (i.e., less than 28°F) and/or costs or losses were incurred. Approximately 86 percent of the reports, as per the filing criteria, were submitted by the growers. Two hundred eighty-seven Damage Reports were also filed by the growers. These reports are required whenever damage is observed. Approximately 90 percent of the anticipated damage reports were submitted by the growers.

At this point in time it is not possible to establish the benefits of improved temperature forecasting to the Florida citrus growers since this

must await test group data collection and analysis and the comparison of the control and test group results. Thus, future efforts will be devoted to a repeat of the previously described data collection and analysis but with the improved temperature forecasting capability being available. A comparison of the test group results with the control group results will then be accomplished. It is felt that a minimum of two frost seasons of test group experience is required since it is likely that during the first season, growers and forecasters will be learning to adapt their decisions and actions to the improved information. Thus, it is likely that the 1977-78 frost season will be a transient one with the steady-state reached by the 1978-79 frost season. The uncertainty of the occurrence of frost during any particular frost season is another factor which leads to the consideration of more than one frost season for the test group.

The data provided by the test group will, as in the case of the control group, yield average cost and loss per event. Both the control and the test group cost and loss per event data will be extrapolated to the annual cost and loss for the Florida citrus industry for an "average" frost season. The difference between the control group and test group annual costs and losses extrapolated to an average frost season will provide an estimate of the average annual benefits which are a direct result of the improved information. These benefits will include the reduction of citrus grower frost protection costs and the reduction of crop losses that are the result of improved decisions which are due to the improved information. The benefit assessment will not include, because of the limited number of frost seasons and, hence, data samples, those benefits which are the result of better marketing decisions made possible by the improved temperature distribution knowledge provided by the SMS data.

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